may start the segregation is hardly sustained by the examples that he brings forward. The "tests of sea-urchins and bivalve shells" are not very often "converted into flint". Casts of their interiors are common enough, and flint often encloses the calcareous tests. The infilling of calcareous ooze has become silicified, like the chalk surrounding the remains. The test, especially when formed of calcite, has resisted pseudomorphism.

There is something inspiring in the conception of a thousand feet of chalk, with an area of some thousands of square miles, acting as a medium for waters which rearrange the silica left by organisms throughout its mass. It remains to be seen if field-observations raise any serious objections to this view. If we could find limestones contorted at so early a stage that the zonal silicification set in at a later date, the zones of flint should be independent of the planes of stratification.[1] But flints seem, as I have previously remarked, to belong to the first stages of consolidation, when the waters are being drawn up or sink down vertically through the mass. These waters group the silica as they diffuse, and they emerge or drain off elsewhere in the form of calcareous springs.

Though flint in other limestones is often spoken of as chert, our considerations must be by no means limited to the siliceous nodules in the Chalk. Reversing the opinions that we formerly held, we may see in the rhythmic deposition of flint an indication that the silica was originally evenly distributed in the mass. When layers of varying texture and mineral composition are present, they check continuous diffusion. The more uniform conditions in the chalk of Upper Cretaceous age have no doubt given us a classic example; but nodular layers, and even regularly surfaced beds of flint, are known to most workers in the Carboniferous Limestone. A fine instance occurs in the steeply dipping strata in a quarry at Ballintemple, east of the city of Cork. The Portland Beds of the south of England, and the white Cainozoic limestones of the Paris Basin, also furnish examples in easily accessible lands.

IV.—Geology at the Seat of War.[2]

By Aubrey Strahan, Sc.D. (Camb.), Hon. LL.D. Toronto, F.R.S., V.P.G.S.

At a time when the resources of every branch of science are being devoted to the furtherance of the War, it is not inappropriate to consider in what way geological research is being turned to account. At first sight it might appear that the work of the stratigraphical geologist, the palæontologist, or the petrographer might be of domestic and academic interest, but would be unlikely to influence the course of a worldwide war. Such researches have received a respectful

[1] The only reference with which I am acquainted as to the relation of flint-zones to earth-movement is the remark by W. Hudleston in the discussion on Wallich's paper that flints are absent from 'flat' beds of Coral Rag at North Grimston, but are present where the beds are bent (Quart. Journ. Geol. Soc. London, vol. xxxvi, p. 92). This interesting observation deserves, and may have received, further investigation.

[2] Presidential Address to the Vesey Club, December 12, 1916 (Abstract).

toleration in this country, but have been regarded as a luxury, to be abandoned first among luxuries in time of stress. I venture to hope, however, that it will not be so necessary in the future as it has been in the past to expend energy in urging the claims of science. In the foundation of the Imperial Trust for Scientific Research we may recognize that at least one good result has arisen from the calamity of war.

The Germans have been active in their application of geology at the Front, but that they have been more active than ourselves must not be assumed from the fact that I speak more freely of their proceedings than of our own. The amount of German literature which has reached me since the outbreak of the War is limited, but it suffices to show that a number of treatises on War Geology has been published, and from one of these I extract some significant passages. One author, writing in December, 1915, remarks that first and foremost they (the Germans) have really begun, in different parts of the Front, to make geologists a part of the Army organization. A staff of geologists has been created and placed under the direction of a Professor of the University of Greifswald for one of the divisions of the Western Front, and an extension of duties arranged for when their present task is finished. Among the subjects mentioned as requiring geological advice are the laying of field railways, the provision of water in co-operation with bacteriologists, the examination of marsh-lands, the finding of road-metal, and the guarding against landslides, which may be brought about by gunfire. Hints are given, too, that much greater use has been made of geological maps for military purposes than can be made known now. In fact, I gather from this author, who is himself a professor of palæontology, that a sufficient and intelligent use of geologists would go far to win the War. He admits, however, that an individual geologist may not be infallible, and he acknowledges that in attack or retreat the first line cannot wait for the geologist's advice. He proceeds to recommend that full advantage should be taken now of examining the innumerable artificial openings which have been made, and gaining such a knowledge of the ground of our neighbours as may be desirable for military purposes. "For," he continues, "the peace will not be an everlasting peace. Who can hope for that? We, whose country has so often been invaded, must therefore prepare to defend ourselves, and as the new battles may very likely be fought on the ground on which our armies are now fighting, our descendants would be justified in reproaching us if we were so short-sighted as not to avail ourselves of the present favourable opportunity of examining the geological character of the field of battle." I invite your attention to the fact that preparation for another war is suggested while the present war is at its height, and that protection against further invasion of Germany is to be obtained by studying the geology of the territories of her neighbours.

In connexion with the operations on the Western Front a comparison of the geology with that of the South of England acquires a special interest. The severance of England from the Continent is, geologically speaking, a recent geographical incident. That the

chalk escarpments of the North and South Downs are continued in the chalk escarpments which overlook Boulogne is obvious, and that the subdivisions of the Tertiary strata with which we are familiar in the London and Hampshire Basins are recognizable in the North of France and in Belgium is well known. Not only so, but the scenery characteristic of each formation is reproduced with fidelity.

In one respect only the Continental deposits differ materially from those of our home counties. Over wide tracts there has been distributed, up hill and down dale, a fine yellow loam, the *limon* of Belgian geologists, which is doubtfully, if at all, recognizable in England. The thickness varies from 100 feet in the valleys to a mere trace on the flanks of the higher hills, where it shades into hill-talus, but the material is generally spread as a mantle over the country regardless of elevation. This is the deposit with which our men are generally in contact in trenches and the smaller dug-outs, and which is in evidence on the clothes of those returning from the Front.

Much has been written on the origin of the *limon*. It has not the character of a stratified subaqueous deposit, and its fossils include no marine and but few freshwater shells. Land shells, however, are embedded in it, with the bones of various herbivorous and carnivorous mammals. Judged by all these characters, its uniformity of grain, its disregard of level, and its fossil contents, it has been attributed in the main to subaerial agencies. It is in fact a dust, distributed by the wind and retained wherever it settles on ground thickly clothed with vegetation. Like the loess, with which it has many characters in common, it appears to have been formed in countries which suffer from extreme alternations of dry and wet seasons.

In dry weather the *limon* readily returns to a condition of dust; in wet weather it forms a mud unlimited in quantity and obstructiveness. But as a material in which trenches and dug-outs can be excavated with the minimum of labour it seems to have found some use. Under the *limon* and for the most part visible only by means of wells or boreholes, lie the Tertiary and Cretaceous formations.

The southern margin of the Tertiary tract, which includes the London and the Belgian Basins, runs near Basingstoke, Guildford, and Canterbury to the coast near Deal. It strikes the French coast south of Calais, and passes thence by Béthune, Mons, Namur, and Liège. As far as Béthune the margin lies within the lines of the Allies as at present situated, but thence southwards it passes into ground occupied by the enemy.

Along parts of the margin the strata, both the Tertiary beds and the Chalk below them, are tilted up at a high angle, as for example near Guildford, and in such a case the Chalk projects in a ridge, typically illustrated in the Hogs Back. But on the Continent the Chalk emerges at a gentle angle, and the passage from rolling Chalk downs to low undulating plains of Tertiary beds is gradual. Indeed, outlying patches of Tertiary beds, from a few acres to a few square miles in area, are scattered abundantly over the higher parts of the downs. Geologically this tract is comparable to many parts of Hertfordshire, Buckinghamshire, Berkshire, Surrey, and Kent, and

the close correspondence of the strata in detail gives a peculiar interest to a study of these parts of England at the present time.

In the London Basin we recognize three groups in the lower Tertiaries, and in the Hampshire Basin the same three groups with other higher Tertiary strata which have been removed from the London area by denudation. The lowest group, resting directly upon the Chalk, is known as the Reading Beds and Thanet Sands with pebble beds. The thickness of the group amounts to 100 feet in places. At its base lies a layer of unworn chalk-flints coated with a green silicate of iron, and interbedded in the sands are clays, often of a vivid red colour.

These characters are reproduced in the *Landenien* of Belgium. The interbedded clay is known as the *Argile de Louvil.*

The Reading Beds pass below the London Clay, and under suitable circumstances the water in them is held down under pressure by that impervious covering. In such cases, when a hole is bored through the clay, the water rises from the sand and overflows at the surface. This used to be the case years ago in parts of London, and well-borers sometimes found themselves in unexpected possession of an uncontrollable fountain which flooded their own and their neighbours' premises. On the Continent an artesian supply is still available in suitable conditions within the margin of the Tertiary basin. The water, however, is potable only near the margin; in the inner parts of the basin, far away from the outer edge, it is too heavily loaded with mineral matter to be usable.

The London Clay, which comes next above the Thanet Sand, has a thickness of 400–450 feet. It corresponds in character, thickness, and fossils to the *Argile de Flandres*, or the *Yprésien* of Belgian geologists, except that in Belgium it consists in the upper part of alternating bands of sand and clay. London Clay has its uses. Almost the whole of the system of tube-railways under London has been constructed in this watertight material. The earlier underground railways, the sewers, and other works were situated nearer the surface, and encountered large quantities of water in the superficial gravels; the tubes were protected by clay above and below, except in a few exceptional localities.

The Bagshot Sands come next above the London Clay. These attain a thickness of approximately 1,000 feet in Hampshire, but in the London Basin have been for the most part denuded away. Parts of them, however, still remain near Aldershot, Bagshot, and Ascot and on the tops of Highgate and Hampstead Hills. Wherever they exist they make their presence apparent by a characteristic scenery of heath or pine forest. In Belgium they are represented by the *Paniselien* and *Bruxellien* Sands, and there also they produce a type of country which is in strong contrast with that produced by the Yprésien Clay. The conspicuous hill on which Cassel stands is composed in the main of Paniselien Sand, though it includes some later formations on its summit. Eastwards, as the Belgian Tertiary basin is approached, the Paniselien Sand comes on in greater force. It forms the bold range of hills which surround Ypres on its southern and eastern sides, and which includes the site of the famous Hill 60.

The Paniselien and Bruxellien Sands absorb a large proportion of the rain that falls upon them, and give out the water as springs at their base, where they rest upon impervious clays or along any interbedded clay-band. Bailleul draws, or used to draw, a part of its supply from a spring of this character in the side of Mount Noir, one of the hills south of Ypres. Ypres was supplied by similar springs at Dickebusch and Zillebeck, but the gathering-ground of the springs includes the scene of some of the most murderous fighting of the war, and it may well be questioned whether water drawn from such an area can be usable. In other parts of Belgium a system, which is rarely seen in Britain, of driving tunnels under the larger tracts of such sands and collecting the water by branching galleries, has been adopted. Brussels is partly supplied in this way.

The Chalk of the South-East of England includes three subdivisions of more or less distinctive lithological characters. The Upper Chalk is a massive type of chalk set with nodules or rows of nodules of flint. This subdivision ranges to upwards of 600 feet in thickness and forms the upper and bolder part of the chalk escarpments. The Middle Chalk is a thick-bedded chalk generally devoid of flints, and the Lower Chalk includes much chalk marl. The Upper Chalk is the source of water of the majority of chalk wells. The Lower Chalk, on the other hand, though it may hold much water, yields it but slowly on account of its marly and almost impervious character. For this reason the Lower Chalk has been much discussed as a suitable stratum in which to drive a tunnel from Dover to Calais. In fact, the small part of the tunnel which has been driven is situated in this subdivision.

In the North of France these subdivisions of the Chalk present much the same characters as in the South-East of England, but there extends from near Calais towards Mons an underground bar, which clearly existed in the Cretaceous sea as a ridge or at any rate an obstruction to the free circulation of currents. The Upper Chalk, though it crosses the bar, changes its character. The whole formation assumes a marly character under Flanders, and loses its value as a reliable source of good water. Herein lies the difficulty of finding water supplies in Eastern and Western Flanders. The Landenien water is often not potable, and the Chalk yields none. The Palæozoic rocks beneath yield salt water, if any, and the uplands of Paniselien Sand are too limited in area to give a sufficient supply by gallery. Under these circumstances recourse has been had to rain and canal water, rendered harmless, as believed, by chemical treatment and filtration. So keenly was the lack of good water felt that a project was on foot before the War to supply the towns of Low Belgium from a source in the Ardennes. The supply had been carried to Brussels, and its further distribution was in progress when the War broke out.

Chalk forms one of the most suitable rocks for dug-outs, provided that the excavations are not carried below the level of the underground water. It is not difficult to excavate, and yet firm enough to stand fairly well. The extensive and elaborate system of underground dwellings recently captured by our troops have been excavated in the Chalk.

For obvious reasons it would be unwise to describe in detail the problems which have arisen for solution at the Front, but it may be legitimate to remind you that tunnels, unlike wells, should be so designed as to keep clear of water, and that the best way of effecting this object is to keep the operations within the limits of a watertight formation, as was done in the case of the tube-railways. An exhaustive study of the thicknesses and inclinations of the strata, and especially of the faults or folds by which they are affected, is required for the purpose. The necessary observations are not easy to make, for the calm reflection required for the solution of a geological problem is apt to be interrupted by the attentions of the enemy. Operations are of necessity hurried and hazardous. It is well also to endeavour to realize the conditions under which our men are working in the tunnels. There is no branch of the Services, whether on the sea or under it, on the ground or in the air, in which pluck and endurance have not been manifested to a degree which would have been scarcely credible two or three years ago. No less are these qualities called for in the men who are working in the bowels of the earth, with the ever-present danger of being forestalled by the enemy and of being buried alive with no possibility of rescue.

The Secondary and Tertiary formations rest upon an undulating plane cut in the Palæozoic rocks, conveniently known as the Palæozoic floor. These ancient rocks have been thrown in the course of geological ages into the most complicated structures. Not only are they folded, but along certain belts of country they have been inverted and their newer members thrust bodily over their older members. The plane therefore cuts across rocks of many ages, ranging from Coal-measures to Cambrian or earlier. In the locating of Coal-measures among these older rocks, under the blanket of Secondary and Tertiary strata, lies the problem of extending the coal resources of the country.

The first step towards accomplishing this in the South of England was taken in Kent, where the existence of Coal-measures was anticipated on geological reckoning many years ago and proved in 1886. It was argued that the Axis of Artois, a belt characterized by intense folding and overthrusting from the south, which ranges past Liège, towards Douai and thence to the coast near Calais, must continue through the South of England, and that there might be coalfields entangled in it in England as on the Continent.

The numerous borings put down in Kent since 1886 have had the result of proving that the Coal-measures there lie in a trough in the Carboniferous Limestone, the axis of which ranges in a north-westerly direction. The dips observable in the cores are usually gentle, and there is nothing to suggest faulting or folding such as characterize the coalfields situated on the Axis of Artois.

It therefore is still a matter of doubt whether the Kent Coalfield is situated on that axis, and not to the north of it, and whether it does not compare in this respect with the coalfield of La Campine. This field was discovered in 1901, and twelve or more shafts were being sunk through the Tertiary beds and the Chalk into the Coal-measures when the War broke out. By some Continental geologists

it is thought likely to be continuous with the Yorkshire Coalfield, by others with the Kent Coalfield, but attempts to follow it in a northerly direction have so far been defeated by the great thickness of Tertiary sands near Antwerp. Apart from the highly speculative question of its extension in either of the directions named, it seems to be comparable to the Kent Coalfield in its relation to the great belt of folding along which the other Belgian coalfields are situated.

V.—Note on *Plectrodus*, the Jaw of an Upper Silurian Fish.

By Arthur Smith Woodward, LL.D., F.R.S.

When fish-remains were first discovered in the Ludlow bone-bed and other horizons of the Upper Silurian series, some of the fragments were regarded as toothed jaws by Agassiz, who described them under the names of *Plectrodus mirabilis*, *P. pleiopristis*, and *Sclerodus pustuliferus*.[1] The same fossils were afterwards considered to be of Crustacean origin by M'Coy,[2] but definitely proved to be fish-remains by the microscopical examination of Harley, who pointed out that while they could not be teeth or jaws, they appeared to him to be "the posterior spines of the cephalic plate of some Cephalaspidian fish".[3] The latter view was adopted by Lankester, who treated the specimens as parts of the cornua of a small Cephalaspidian head-shield which he named *Eukeraspis pustuliferus*.[4]

Egerton[5] also described similar fossils as jaws, and among these was one specimen from the Downton Sandstone (Brit. Mus. No. 45969), which I studied some years later and considered to resemble a fish-jaw rather than a cornu of *Eukeraspis*.[6] In 1893 Rohon[7] made a microscopical examination of several fragments both from the Ludlow bone-bed and from the well-known Upper Silurian limestone in the Isle of Oesel (Baltic Sea), and concluded that while some of the specimens ascribed to *Plectrodus* and *Sclerodus* were Cephalaspidian, others were certainly not of this nature. He described the latter as exhibiting "denticles and tubercles of vasodentine, and the base not formed of true bony tissue but of a bone-like substance". In 1898 I found in the Museum of Neuchâtel three of the original specimens from the Ludlow bone-bed which were described by Agassiz (labelled "Rev. Wm. Evans, 1836"), and two of these (figured in *Siluria*, pl. iv, figs. 15, 25) appeared to me distinctly jaw-like. In 1910

[1] L. Agassiz, in Murchison's *Siluria*, 1839, p. 606, pl. iv, figs. 14–32, 60–2.

[2] *Pterygotus pustuliferus*, F. M'Coy, Quart. Journ. Geol. Soc., vol. ix, p. 14, 1853.

[3] J. Harley, "On the Ludlow Bone-Bed and its Crustacean Remains": Quart. Journ. Geol. Soc., vol. xvii, p. 544, 1861.

[4] E. Ray Lankester, *Fishes of the Old Red Sandstone*, pt. i (Pal. Soc., 1870), p. 58, pl. xiii, figs. 9–14.

[5] P. M. G. Egerton, "On some Fish-remains from the Neighbourhood of Ludlow": Quart. Journ. Geol. Soc., vol. xiii, p. 288, pl. x, figs. 2–4, 1857.

[6] A. S. Woodward, *Catalogue of Fossil Fishes in the British Museum*, pt. ii, 1891, p. 195.

[7] J. V. Rohon, "Die Obersilurischen Fische von Oesel": Mém. Acad. Imp. Sci. St. Pétersbourg [7], vol. xli, No. 5, p. 95, 1893.